Celestial Object and Temperature Detection using Fourier Transform

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***Abstract*— This paper describes methods to automate the discovery and tracking of celestial bodies. These can be applied by astronomers using radio telescopes to ease their telescope management tasks. However, with the advancement in space exploration this particular system can actively track and avoid debris on both manned and autonomous spacecrafts.**

***Keywords*— Electromagnetic Spectrum, Radio Signal, Video Processing, Fourier Transform, Celestial Objects.**

I. Introduction *[1]*

Radioastronomy has been advancing for generations, from gazing at stars to detecting and accurately locating new stars and planets in the universe. This universe has innumerable stars and planets which are yet to be discovered. Fortunately, the discovery of all stars, planets and galaxies till date has been made possible by the advanced radio telescopes. Every object in the universe has characteristic spectra which is the production of electromagnetic radiations with unique frequency and wavelength. These radio telescopes help detect these electromagnetic radiations.

But two problems arise, first when the radio telescope captures the radio waves, they have divergent radiations which are quite jumbled up. This creates difficulty to distinguish all the electromagnetic radiations. The second problem is that the captured waveforms are in time domain, so the frequency is yet unknown which is one of the most important data for astronomers. So, these problems make it unable to detect objects. Thus, Fourier Transform helps to resolve this problem.

Fourier Transform is a mathematical tool that divides waveform into a representation only consisting of sines and cosines. It transforms any wave into the addition of sinusoidal functions. Fourier transform makes the world look from a unique insight and has been quite an advantage in real-world applications including radio astronomy. In radio astronomy, it converts these waveforms from time domain to frequency domain which can be further used to convert into thermal images.

These thermal images are helpful to astronomers as they help them to detect objects in the universe. And in today's advanced technology image processing can increase the accuracy of detecting these objects where the astronomers do not have to waste their time figuring out the object in the image provided. These recognized objects can be used for further analysis and research in future.

II. Literature Review

A. Radio Telescope [2]

As we know the optical telescopes collect visible light, focus and amplify it for analysis purposes, Radio telescopes collect radio waves (light radiations) and similarly focus and amplify it for analysis. These are generally used to study the radio waves emerging from celestial bodies such as stars, black holes, galaxies, etc. Radio telescopes are specially designed to observe the longest wavelengths of light ranging from 1mm to 10m and for better accuracy, the frequencies are measured. But these naturally occurring signals are extremely weak as they require a higher amount of time to reach us from space.

The major components of a radio telescope are an antenna to pick up the radio interference and a receiver to detect the signals. As the signals are weak, powerful antennas like the parabolic dish antenna are used. Due to these, the signals bounce to a single point and according to the frequency channel of the receiver, the specific signals are read for further research. These funnel-shaped dishes are called feed horns which detect the exact pulse waves from the antenna.

The sizes of these feed horns are based on environmental conditions such as wind, temperature, and pull of gravity. They follow the position in the sky by copying the Earth's axis of rotation and move against it. Most modern radio telescopes use a digital computer to tilt and turn the axes along the sky.

B. Data Processing from Telescope [2][3][6]

Modern radio telescopes observe numerous frequencies at once and divide the frequency in separate channels over a range of megahertz.

While clicking an image we need to keep the camera shutter open for a long time. Similarly, the telescope remains in the range of the radio source signal for a larger amount of time and after collecting the data, random noise signals are averaged over that time.

These radio telescopes are placed according to the different wavelengths of the electromagnetic spectrum (e.g., Fig. 1) and use a method known as Interferometry.

For this paper, we need to look at the radio spectral lines which at specific frequencies reveal the origins in atoms and molecules in both ionized and neutral gas clouds. Furthermore, spectral lines are observed in some distant galaxies providing insights into the early development of the Universe.

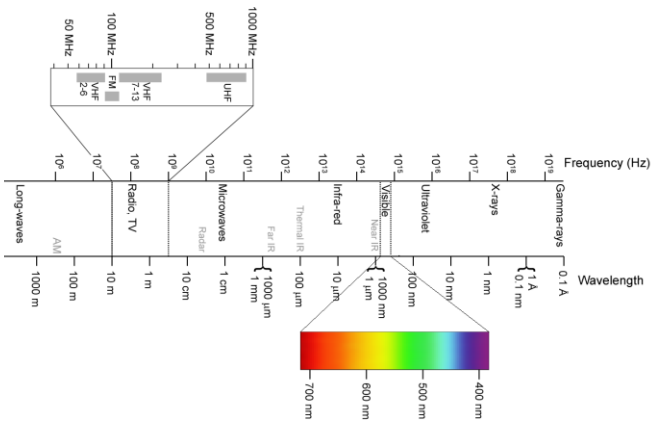

Fig. 1. Range of Electromagnetic Spectrum

C. Detection of Temperature and Distance [4]

The type of electromagnetic radiation emitted by celestial objects is determined by the temperature. This temperature is the measure of the average motion of the particles in an object. For example, in a hot body, the particles have rapid vibrations and a higher number of collisions due to which emission of energy is high which gives them a higher frequency. The wavelength at which maximum energy is emitted is calculated with the help of Wien's Law -

$$\lambda_{max} = \frac{3 \times 10^6}{T}$$

As we know the wavelength of radio waves is greater than 10^9, we can find the temperature radiated by objects which fall under the range of less than 10K.

When there is a need to predict the luminosity (absolute magnitude of radiated electromagnetic power) of a celestial object, astrologists create models of these structures. In this case, only the apparent magnitude is available which consists of the distance parameter. Secondly, accurate distances on an extragalactic scale can determine the age of the celestial object. Astronomical unit (AU), Light year (ly), Parsec (pc) are some of the units used to specify astronomical distances.

III. METHODOLOGY.

A. Obtaining Radio Image

As we know taking an image using a Radio Telescope involves getting a long video of the skies. This video is essentially one continuous shot, which contains the value of the signal detected by the antenna at one point. It is essentially scanning, with the assumption that the signal obtained is periodic. We can consider every few seconds of the recording to be that of one point, thus we get a continuous signal of that point (e.g., Fig. 2.).

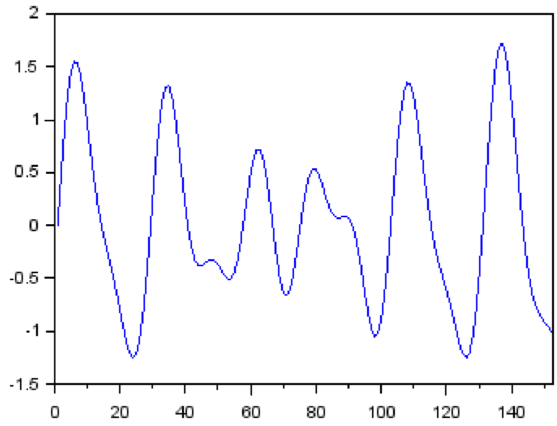

Fig. 2. Input to Radio Telescope

B. Frequency Analysis using Fourier Transform

Applying the Discrete Fourier Transform (DFT) to this signal gives us a Fourier Graph, and thus the frequencies of the signal's contributing to the original signal. The frequency (or the signal) with the largest contribution to the recorded signal is selected to obtain a temperature value. The largest peak in the Fourier graph corresponds to the frequency of the signal with largest contribution to the recorded signal.

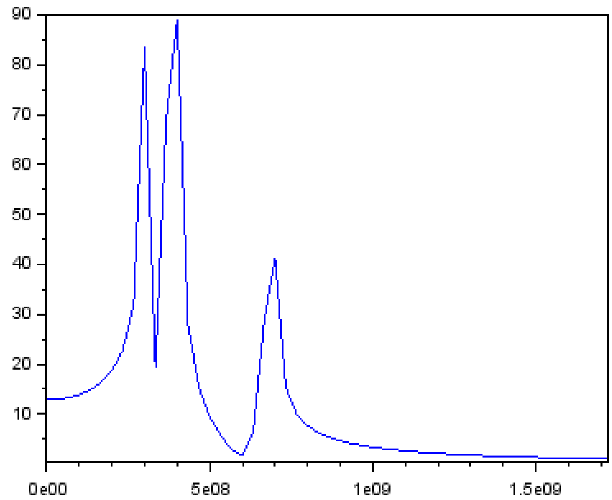

Fig. 3. Fourier Transform of Input Signal

C. Obtaining Temperature and RGB Image

Temperature of a pixel is determined using Wien's Law. The temperature output is then converted to RGB using conversion formulae:

$$RGB = \frac{(\text{pixel Temp} \times 16777215)}{10^7}$$

$$R = \frac{RGB}{256^2}$$

$$G = \frac{RGB}{256}\,\mathrm{mod}(256)$$

$$B = RGB\,\mathrm{mod}(256)$$

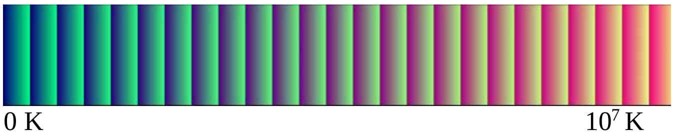

Fig. 4. Temperature Colour Map

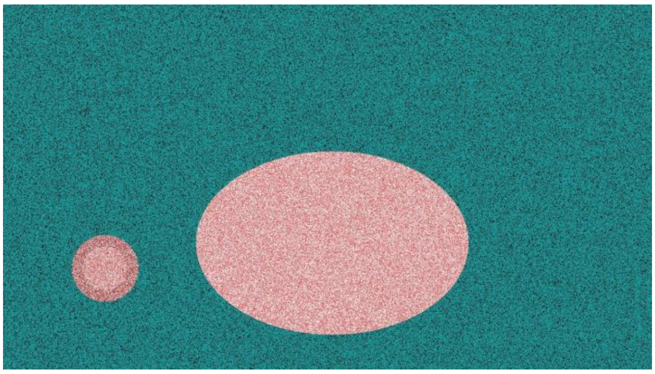

Fig. 5. Thermal Image after conversion

D. Detection of Celestial Object

1) *Conversion to HSV*: The temperatures we have calculated are based on the frequencies of the radio signal. Therefore, to differentiate between the frequencies, we separate the image luminance (intensity) of the image from the color information. We convert the RGB image to its HSV color space as seen in Fig 6.

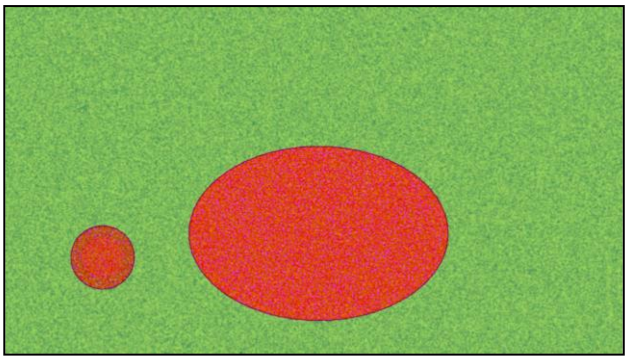

Fig. 6. HSV Image

These HSV ranges are divided into a lower range and a higher range. Let us consider the maximum component to be the Value (V), the minimum component to be the intensity (C), and the mid-range to be the lightness (L). We can calculate the Hue and Saturation using the formula given below:

$$H = \begin{cases} 60^\circ \cdot \left(0 + \frac{G-B}{C}\right), & \text{if } V = R \\ 60^\circ \cdot \left(2 + \frac{B-R}{C}\right), & \text{if } V = G \\ 60^\circ \cdot \left(4 + \frac{R-G}{C}\right), & \text{if } V = B \end{cases}$$

$$S_V = \frac{C}{V}$$

$$S_L = \frac{C}{1 - |2V - C - 1|}$$

2) *Thresholding of the Image:* Now we threshold the image to create a mask of grayscale colors which will be used to isolate the HSV color range of the celestial objects from the surroundings, with the help of the lower and upper limits as seen Fig. 7.

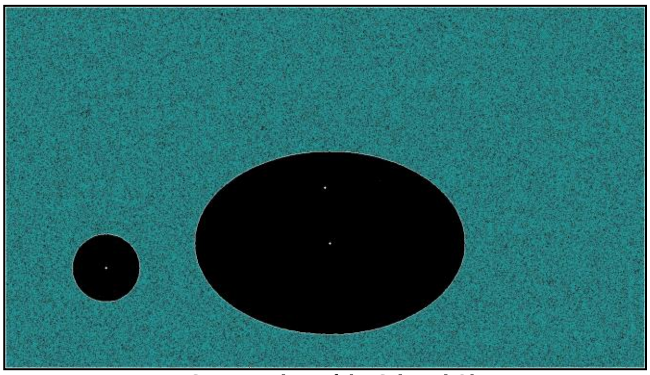

Fig. 7. Contour Edges of the Celestial Objects

3) *Masking of the Image:* The mask created in Section B.2 is used to extract the portion of the image we require (i.e., The Celestial Object) (e.g., Fig. 8.).

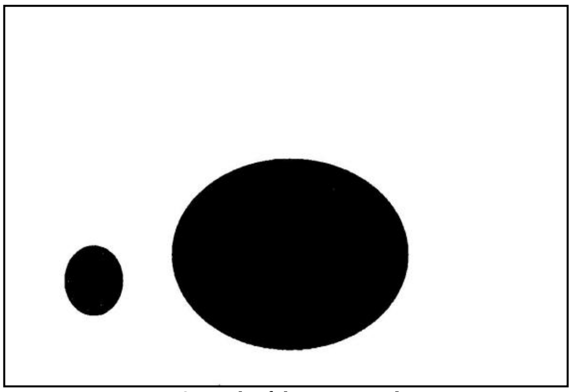

Fig. 8. Mask of the contour edges

4) *Detecting the Edges of the Result:* As we know, the universe consists of numerous celestial objects and we only want to detect the ones which are in the range of the telescope's specifications. Therefore, we find the contours of the detected object which helps us to detect the edges as seen in Fig. 9.

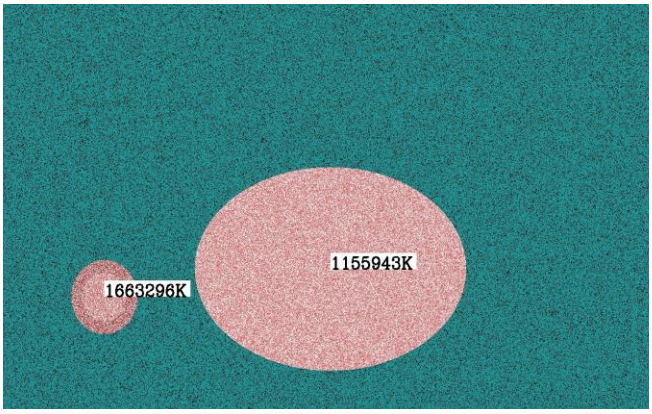

Fig. 9. Temperature of the Celestial Object

IV. CONCLUSIONS

Detection of objects using Fourier Transform has made astronomers work easy by providing them detected objects directly, with their frequency and temperatures mentioned. This can be used by any astronomer exploring the universe from any place which can be both on Earth or in outer space. The whole system is automated, so no astronomer needs to provide any instructions to make the system run. Also, these images provide more information to the astronomers helping them in their research as well as devote more time towards analysing the object detected thus making it valuable to astronomers.

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